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ABSTRACT

This study, which was concerned with the ways in which actions can be elaborated and can influence children's awareness of actions, examined the relationship between action and awareness during childrens' performance on the Towers of Hanoi problem. A total of 94 children between the ages of 6 and 8 years were asked to solve a three-disc version of the problem and to describe how they found their solutions. Aspects of performance investigated were subjects' actual performance on the problem, their awareness of their problem-solving activities, their ability to modify their actions in order to adapt to new problems, and the effects of various training procedures on their performance and awareness. Findings suggested that performance can be markedly improved through a variety of training procedures. Performance on the three-disc problem improved as a result of subjects' repeated practice, observation of the completion of the problem, and viewing of a videotape of a prior performance. Distinctions between the three training conditions could be seen in the way the children described their actions and in the way they were able to modify their activities to deal with complicated problems. (RH)

Children's awareness of actions: Getting a hand on conscic sness

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In Piaget's last works, he turned from the structural description of the logico-mathematical properties of operative thought to an investigation of the functional characteristics of the way a subject experiences the acquisition and growth of knowledge (Bullinger & Chatillon, 1983). This shift represents an important re-orientation in Piagetian theory from the early concerns with epistemology to a more focused concern with the subject's psychological experience (Brief, 1983). In these last works, Piaget examined children's reactions to contradictions (1974), the relationship between unsuccessful performance and understanding a problem (1978), and children's consciousness of successful actions (1976, also see, 1977). In these studies Piaget attempted to elucidate the relationship between cognition and children's functional activities.

In the "Grasp of Consciousness" (1976) Piaget was concerned with the way in which a subject becomes aware or conscious of his or her actions in a situation. Through a series of studies, children were asked to solve very simple problems and then, to give an account of how they solved the problems. The findings revealed that children's conscious awareness of actions was not easily achieved. Being able to successfully perform an action did not ensure that the children were fully aware of particular aspects of their performance. Instead, the children became aware of their actions through a process of conceptualization, i.e., the children gradually came to comprehend different aspects of their actions. Piaget described how in coming to consciousness, the children's understanding proceeded from the "periphery to the center" of the action. That is, the children were first aware of the periphery of their acts -the initial goal and outcome of the act; and gradually, they became aware of the central, mediational or regulatory aspects of the action.

Piaget was particularly interested in explaining why awareness or cognizance, as he called it, should come about. He recognized that in many instances a failure to successfully perform an act may motivate attention to the means of carrying out the act in order to make an adjustment. However, consciousness occurs even when an action is carried out successfully; thus, for Piaget, consciousness had to be understood in a broader context. Piaget argued that consciousness of actions, regardless of their success or failure, emerges from the **assimilation of the functional** p^th of the behavior itself (1976, p.336). It was through the repitition and elaboration of an action that a child becomes aware of first, aspects of either the intention or the outcome of an act, and gradually, coordinates the intention and outcome into a full conceptualization.

The present paper is concerned with the way in which actions can be elaborated and influence children's awareness of actions. In this study the relationship between action and awareness was examined through children's performance on the Towers of Hanoi problem (see Figure 1). This problem has received considerable attention in the adult problem solving literature because its clear objective and discrete steps in finding a solution allow a detailed analysis of problem solving (Simon & Hayes, 1976). Piaget used this problem in his studies of consciousness, and it has been further examined by Klarh and Robinson (1981). In this study, **children** between the ages of six- and eight-years of age were asked to solve a three disc version of the Towers of Hanoi problem and were then asked to describe how they achieved their solutions. There were several areas of interest examined in this study: the children's actual performance on the problem, their awareness of their problem solving activities, their ability to modify their actions in adapting to

new problems, and the effects of various training procedures on children's performance and awareness.

Ninety-four children participated in this study. Equivalent numbers of children were choosen from first-, second- and third-grades. The children were seen individually on three separate occasions, approximately one week apart. During the first meeting, the children were given a series of pre-training tasks to assess cognitive capabilities. The tasks included a Peabody Picture Vocabulary test and several measures of logical skills (such as a seriation task, a conservation of liquid quantities task and classification tasks), as well as the three disc Towers of Hanoi problem. During the second meeting, the children were randomly assigned to one of three training conditions. In one condition, the children observed the experimenter model the most efficient (seven move) solution to the three disc problem. In a second condition, the children were given the opportunity to practice solving the problem. In this condition the children received minimal encouragement from the experimenter, and were only encouraged to "try different things" and to "move the pieces around". In a third condition, the children were allowed to view a video presentation of their prior performance on the problem task. Here, the children were encouraged to watch the tape to see if they could figure out a better way of solving the problem. In each condition, the children were trained until they reached the criterion of sucessfully completing the problem. Immediately following the training, each child was asked to solve the three disc problem. The children's performance was measured in terms of the number of moves necessary to complete the problem, the time taken to complete the problem, and the number of errors that were made (i.e., breaking rules, starting over from the beginning). After the children solved the problem, they were asked to

describe how they achieved their solutions.In order to examine the effectiveness and scope of the training conditions, the children were then asked to solve three generalization tasks: first, they solved a three disc problem but to a different peg or end point (the middle peg); second, they solved a four disc problem; and third, at the end of the session, the children solved the original three disc problem again. During the third meeting, approximately one week after training, the children were seen again and were asked to solve the three disc problem, describe how they reached their solutions and solve the three generalization tasks.

The training conditions were not significantly different in terms of age ($F(2, 93)= .15$, $p > .05$), and there were no significant differences between groups in terms of their performance on the PPVT ($F(2, 93)=1.45$, $p > .05$). Differences between the training groups in terms of the children's performance on the Piagetian tasks were examined by way of chi squared analyses. There were no significant associations between training groups and performance on the seriation task (χ^2 $(2)=2.15$, $p > .05$), the conservation task ($\chi^2(2)=3.29$, $p > .05$), and the classification tasks ($\chi^2(2)=.331$, $p > .05$). The children's initial performance on the three disc Towers of Hanoi problem are presented in Table 1. Overall, 46.7% of the children in the Video condition completed the problem prior to training, 51.5% in the Practice condition did so, and 45.2% in the Model condition completed the task. There was no significant association between the three training conditions and the frequency of completing the three disc problem ($\chi^2(2)=2.25$, $p > .05$). A series of two-way (Condition by Grade) analyses of variance were performed on the number of moves necessary to complete the problem, the time, and the number of errors. The results revealed that there were no significant main effects or interactions for the number of

moves and errors. For the time spent on the problem, there was a significant main effect for grade ($F(2, 93)=3.77$, $p<.05$); however, there was no significant main effect for condition ($F(2, 93)=.741$, $p>.05$), and no significant interaction ($F(2, 93)=.78$, $p>.05$). Post hoc comparisons revealed that the third grade children took less time ($\bar{X}=172.45$) to solve the problem than did the first ($\bar{X}=219.45$) and second ($\bar{X}=222.1$) grade children. Thus, it appears that the children assigned to the three training conditions were equivalent in terms of their age, PPVT scores, their performance on the Piagetian tasks, and their performance on the three disc Towers of Hanoi problem.

The children in each of the training conditions were trained until they reached the criterion of successfully completing the three disc Towers of Hanoi task. All of the children who participated in the study reached the criterion; and as can be seen in Table 1, there were dramatic reductions in the number of moves, time and errors after training. Further, it appears that there were no significant differences between the three training conditions for the number of moves ($F(2, 93)=.67$, $p>.05$), time ($F(2, 93)=.75$, $p>.05$), or errors ($F(2, 93)=.44$, $p>.05$). Thus, the Video, the Practice and the Model conditions all improved the children's performance on the three disc problem and there were no significant differences between the three training conditions. We feel this is noteworthy, given the dramatic differences between the three types of training procedures. In the Model condition, the children were literally given the most efficient (seven move) solution to the problem. The training was very short and the children were extremely confident that they knew how to complete the problem themselves. Despite encouragements to "watch again", many of the children opted to try the problem for themselves. In contrast, in the Practice

and Video conditions, the children were not provided with any specific information about how to solve the problem. The training procedures took considerably longer and the children often opted to practice or see the tape again. Thus, despite the directness of the Model condition, all three training conditions were effective in improving performance. Also, as can be seen in Table 1, the effects of the three conditions lasted over a weeks time.

Following the completion of the three disc problem, the children were asked to describe how they achieved their solutions. Overall, the children had no difficulty responding to such an open-ended question: 70% of all the children attempted to give some verbal account of how they solved the problem. However, there was a significant association between the different training conditions and the children's awareness of how a solution was aahieved ($\chi^2 = 6.54$, $p < .05$). In the Video condition 83% of the children attempted an explanation of some sort, 76% in the Practice condition did so, and in contrast, only 55% of the children in the Model condition attempted some explanation. This relationship between training condition and the tendency to give an account of performance was further examined for each of the grade levels. In Table 2 are the percentages of children who gave a verbal account of their actions presented by condition and grade level. It appears that the influence of the different training conditions was greatest for the first grade children. In the Video condition 70% of the first grade children gave some account of their performance, while only 58% in the Practice condition do so, and only 50% of the children in the Model condition gave a response. Among the second graders, the children in the Video and Practice conditions showed a strong tendency to provide a verbal response, while relatively few in the Model condition did

so. The third grade children tended to respond regardless of training condition.

Among the children's attempts to give descriptions of their performance, four types of descriptions were distinguished. The first type was an inaccurate or fragmented description. For example, one child described, "I just moved them " or another described, "I just watched you" or several others re-stated the rules or mentioned the end point. The second type of description involved a move by move account of the solution, accompanied by an actual demonstration of the moves. The third type of description was an accurate move by move account of the performance that was not accompanied by a demonstration of moves. The fourth type of description was not a move by move account but instead, the children attempted to conceptualize an essential aspect of the solution. For example, one child described how "You have to play leap frog with the discs", while another child pointed out how, "You have to move backwards before you can move forward." The percentage of these four types of responses are presented in Table 3 by condition. A chi squared analysis revealed that there was a significant relationship between type of response and training condition ($\chi^2(2) = 14.27$, $p < .05$). As can be seen in Table 3, incomplete responses were most frequent in the Model condition, descriptions in action were most frequent in the Video condition, verbal description were equivalent across all three training conditions, and there were relatively few conceptualizations.

Next,the effects of the training conditions were examined with regard to the children's performance on the generalization tasks. These tasks were given immediately after training, and again one week later. In Table 4 the performance scores for the three generalization tasks are presented by Training condition and time. Two-way analyses of variance (Condition by Grade)

were performed for each of the generalization tasks on each of the performance scores. On the New Peg generalization task, it was found that overall there were no significant main effects for any of the three performance measures; however, first grade children in the Model condition took significantly more moves ($\bar{X}$=15.3) and more time ($\bar{X}$=109.8 seconds) to the solve the problem than did the first graders in the Practice ($\bar{X}$ moves=9.3, $\bar{X}$ time=54.1) or Video ($\bar{X}$ moves =10.6, $\bar{X}$ time =64.8) conditions.

For the four disc Towers of Hanoi problem, the results revealed that the children in the Model condition took significantly more moves ($\bar{X}$=44.48) and more time ($\bar{X}$=231.1 seconds) than did the children in either the Practice ($\bar{X}$ moves =34.7 ; $\bar{X}$ time=163.3 seconds) or the Video conditions ($\bar{X}$ moves=28.87 $\bar{X}$=140.63 seconds). These differences were most pronounced for first graders but were maintained for the children in all three grades. Finally, with regard to the delayed three disc problem, the results revealed no significant main effects or interaction on all three performance measures.

As can be seen in Table 4, the children's performance on the generalization tasks seemed to improve between the training session and the third meeting, and also, the differences between the three training conditions were not as pronounced. A series of three way (Condition by Grade by Time) multiple analyses of variance were performed for each of the generalization tasks on each of the performance scores. For the delayed three disc Towers of Hanoi problem, there were no significant main effects and no significant interactions. The performance scores did not significantly improve from the training session to the third meeting and there were no significant differences between the three training conditions. With regard to the New Peg problem, all of the children significantly improved

for the time that was required to complete the problem during the third meeting. There were no significant differences in the number of moves that were required or in the number of errors that were made. Further, there were no significant differences between the three training conditions on any of the performance scores. With regard to the four disc problem, all of the children improved for the time that was required to complete the problem during the third meeting. And only the children in the Model condition significantly reduced the number of moves that were required to complete the problem. However, some of the differences between the training conditions were maintained during this third meeting. The children in the Video condition solved the four disc Towers of Hanoi problem in significantly fewer moves ($\bar{X}$=25.7) and in less time ($\bar{X}$=105.8 seconds) than did the children in the Model Condition ($\bar{X}$ moves=38.68; $\bar{X}$ time=120.28). It seems likely that the children's improvements during the third meeting were due to the children's added familiarity with the Towers of Hanoi problem. By the third meeting, all of the children not only experienced the various training procedures but had also performed the full array of generalization tasks at the end of the second meeting. This additional practice provided by the generalization tasks, not only could account for the children's overall improvements during the third meeting but also, may account for the lack of distinctiveness between the three training conditions. Nonetheless, some of the distinctions between the training conditions were maintained. On the four disc problem, the children in the Video condition completed the problem in fewer moves and in less time than did the children in the Model condition.

Throughout his work, Piaget has maintained the importance of action in the establishment of knowledge. And, in his last works he attempted to

examine the interiorization of action into conceptualization. Piaget argued that it was the elaboration of action, or the assimilation of the functional path of behavior itself which influences cognition. The present study was concerned with the different ways in which an action might be elaborated and the influence this might have on children's awareness. The children's actions in solving the Towers of Hanoi problem were elaborated in three very distinct ways. The findings suggest that performance can be markedly improved from a variety of training procedures. The children's performance on the three dic problem improved as a result of observing a model complete the problem, by repeated practice, and from viewing a video tape of a prior performance. While these various training procedures did not differentially affect performance on the three disc problem, it does appear that there are distinctions between the three training conditions. The distinctions could be seen in the way the children described their actions; also, the distinctions were evident in the way the children could modify their activities to deal with more complicated problems. It appears that each of the training conditions set a particular context for the elaboration of actions, and that these different settings influenced the children's awareness of their actions and their ability to modify and extend their actions. In this sense, a particular context for the elaboration of the functional path of behavior seems to be an important link to consider in understanding the relationship between action and awareness. It would seem that a further understanding of this relationship would require a detailed investigation of the ways in which the children elaborated and assimilated their actions in each of the particular contextual settings.

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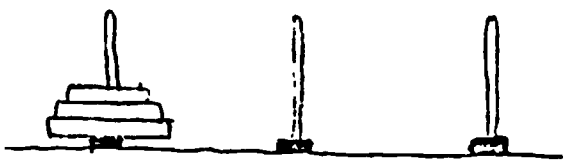

Starting Condition

Ending Condition

Figure 1. The Towers of Hanoi Problem. The child is asked to move the pyramid of towers from the first post to the last post. The child must move only one disc at a time, never put a large disc on top of a smaller one, not rest on the table, or hold a disc in his hand while another is moved. After this, the interviewer asks the child to explain to him step by step how to move the tower.

Table 1

Mean Performance Scores (# of moves, time & errors) for the 3 disc problem presented by Training Condition and Time.

	Video Condition			Practice Condition			Model Condition		
	# of Moves	Time	Errors	# of Moves	Time	Errors	# of Moves	Time	Errors
Time 1	16.83	216.97	4.25	18.37	209.22	5.14	17.20	230.24	3.50
Time 2	10.41	44.96	.12	10.59	37.89	.22	9.79	35.43	0.30
Time 3	10.80	34.04	.04	9.73	35.96	.03	8.68	29.36	0.00

Table 2.

Percentage of children who provided a verbal account of their actions presented by Condition and Grade.

	Video Condition	Practice Condition	Model Condition
First Grade	70	58	50
Second Grade	90	80	45
Third Grade	90	80	70

Table 3.

Percentage of types of responses presented by Condition.

	Video Condition	Practice Condition	Model Condition
Incomplete Responses	16.6	24.2	45.2
Descritions in Action	43.3	24.2	12.9
Descriptions	36.6	45.4	41.9
Conceptual	3.1	6.1	0

Table 4

Mean Performance Scores (# of Moves, time, errors) for the Generalization Tasks presented by Training Condition and Time.

	Video Condition			Practice Condition			Model Condition		
	# of Moves	Time	Errors	# of Moves	Time	Errors	# of Moves	Time	Errors
New Peg									
Time 2	11.87	67.83	.31	11.37	49.63	.34	13.6	84.68	.53
Time 3	12.36	45.00	.09	10.96	38.23	.00	11.80	46.28	.20
4 Disc Problem									
Time 2	28.87	140.63	.50	34.70	163.36	1.36	44.48	231.12	1.40
Time 3	25.70	105.80	.13	32.60	110.72	.12	38.68	120.28	.28
Delayed 3 Disc Problem									
Time 2	11.54	38.33	.08	10.70	39.33	.22	8.82	30.29	.08
Time 3	10.82	34.04	.04	9.73	35.96	.03	8.68	29.36	.00